# Study of the effect of octupoles on the proton beam at 150GeV

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**Objective:**

- Suppress p-beam transverse coherent instabilities at 150GeV with the help of the tunespreads introduced by octupoles ⇒
- relax requirements on chromaticity ⇒
- improve the lifetime of both protons and pbars.

**Some basic facts:**

- Usually broad-band impedance dominates shifting coherent tunes down (in the same direction the space-charge is shifting the incoherent tunes);
- To activate the space-charge tunespread one should introduce an additional tunespread of the same order by external multipoles;
- Cross-anharmonicity is more efficient in suppressing instabilities:

For a single octupole of length $L$ and strength $K_3 = \frac{1}{B\rho}\frac{\partial^3 B_y}{\partial x^3}$

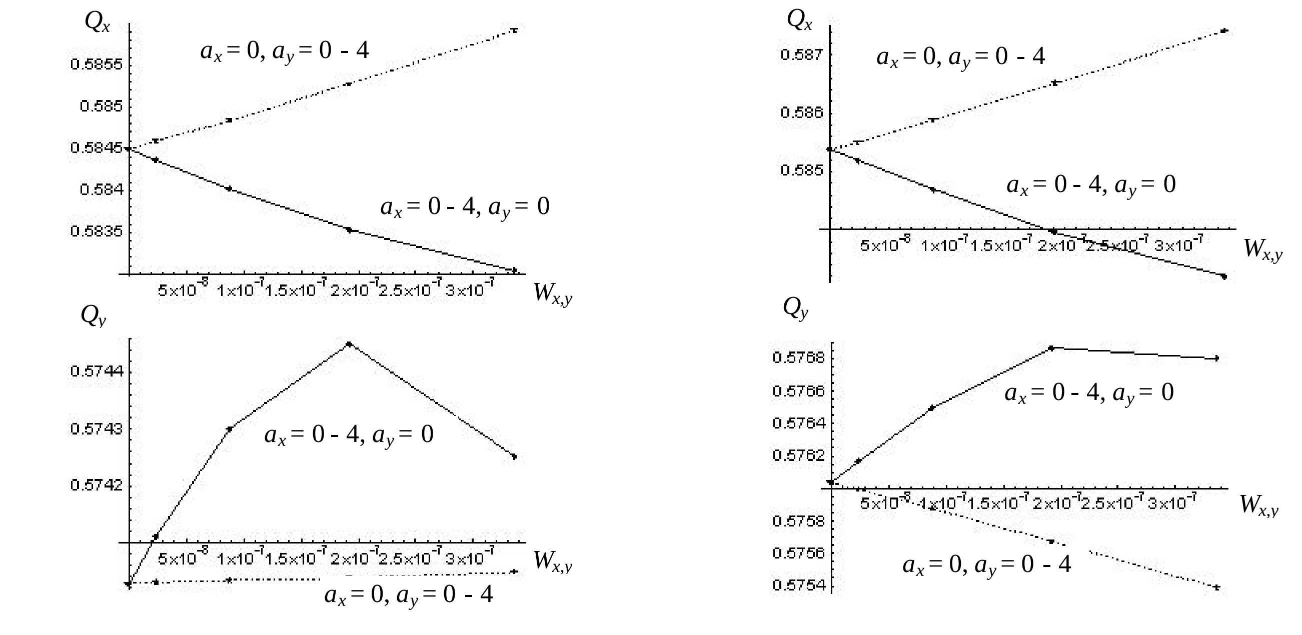
$$\frac{\partial Q_x}{\partial W_x} = \frac{\beta_x^2 K_3 L}{32\pi}, \quad \frac{\partial Q_x}{\partial W_y} = -\frac{\beta_x \beta_y K_3 L}{16\pi}, \quad \frac{\partial Q_y}{\partial W_y} = \frac{\beta_y^2 K_3 L}{32\pi},$$

where $W_{x,y} = \varepsilon_{rms} a_{x,y}^2 / \sigma_{x,y}^2$ are the Courant-Snyder invariants.

**In Tevatron at 150 GeV:**

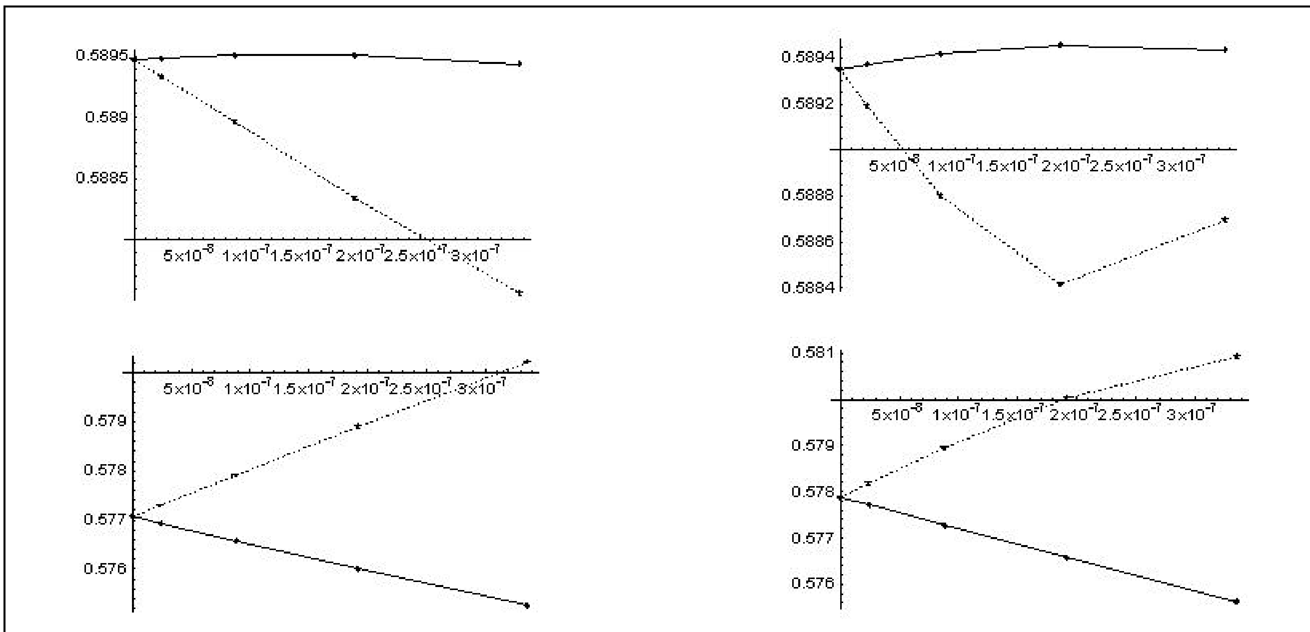
- Measured tuneshift with 200e9/bunch ~ -0.002 (coherent?), whereas the space charge tuneshift is of the order of 0.001;
- To produce $\Delta Q_{x,y}$ ~ 0.001 within 95% emittance $K_3L$=5m$^{-3}$ in both TOZD or TOZF octupole circuits is enough (according to the linear formula);
- This requires 4.17A current in the circuits out of 50A available

## Calculated tunes vs amplitudes (MAD with magnet errors except for Lambs)




**proton helix** **pbar helix**

Old helices, no octupoles




**KOZF=5, KOZD=5** **KOZF=7, KOZD=5**

Old pbar helix with TOZF, TOZD octupoles on

**Measurements**

1) uncoalesced beam, chromaticities at Ch=55, Cv=26

| $I_{TOZF} = I_{TOZD}$ | proton | pbar | central |
|---|---|---|---|
| 0 | 9.6/8.4 | 6.4/8.0 | 7.3/8.7 |
| 4A | 8.3/8.9 | 8.5/7.3 | 7.3/8.2 |

2) 1 coalesced bunch 210e9:

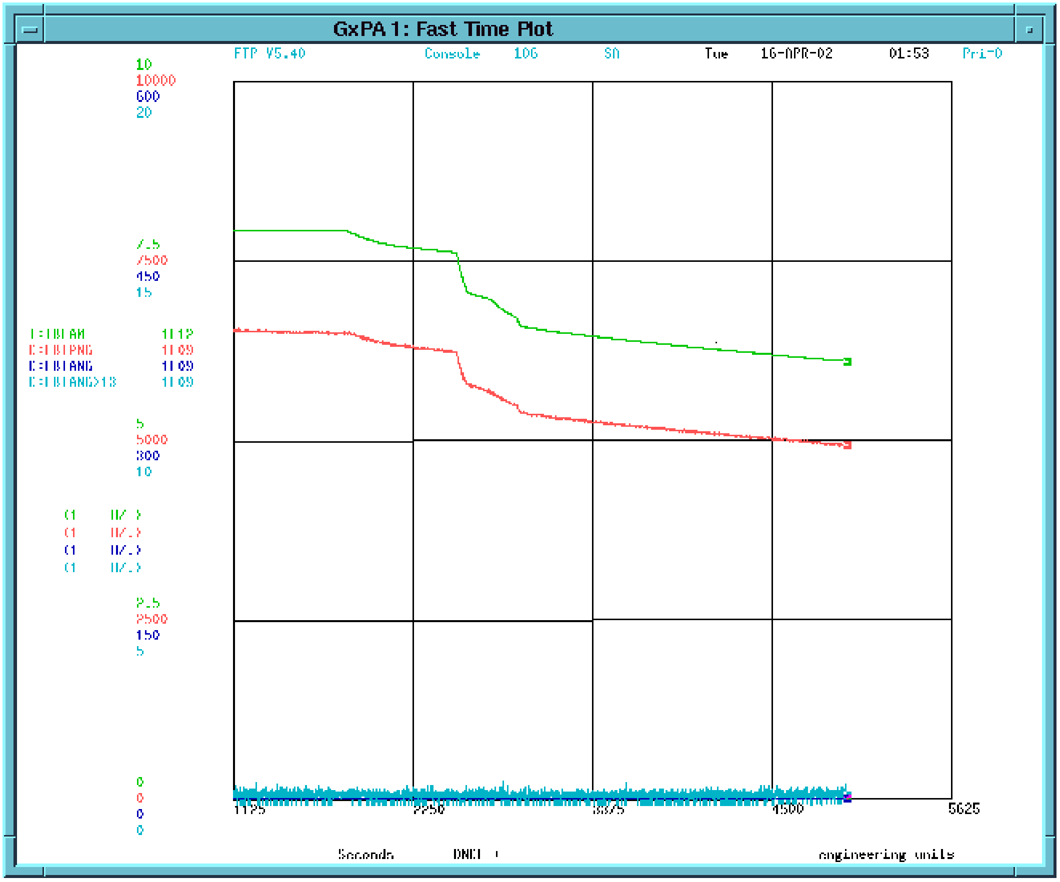
| orbit | $I_{TOZF}$ | $I_{TOZD}$ | Ch | Cv | |
|---|---|---|---|---|---|
| central | 4 | 4 | 45 | 16 | - lost due to vertical instability |
| | 2 | 4 | 46 | 17 | - the same |
| proton | 2 | 4 | 47 | 18 | - on the verge of it |
| | 3 | 4 | 46 | 17 | - the same |

3) 36 bunches initial FBIPNG=6.6e12:

| orbit | $I_{TOZF}$ | $I_{TOZD}$ | Ch | Cv | |
|---|---|---|---|---|---|
| central | 3 | 4 | 51 | 22 | - on the verge of horiz. instability |
| | 6 | 4 | 51 | 22 | - **larger** horiz. Schottky signal |
| | 4 | 5 | 51 | 22 | - no change |
| proton | 4 | 4 | 48 | 19 | - on the verge of horiz. instability |
| | 4 | 4 | 51 | 22 | - Schottky signal calms down |

**- these settings seem to be optimal rendering the lifetime in excess of 6h**

We did not tried to lower vertical chromaticity separately, it seems quite possible.




**Proposals:**

<u>*The next study.*</u>

With the found settings as the starting point

1. Correct coupling on the helices with the octupoles on and check the real values of chromaticities.
2. Try to lower vertical chromaticity separately (seems to be feasible).
3. Check the pbar lifetime – if better, the octupoles can be used during injection and switched off (with restoring chromaticities to the usual values) just before the ramp.

<u>*Longer term.*</u>

Look at the possibility to increase horizontal tunespread and/or to introduce the differential horizontal chromaticity with the help of TOF39S, TOD39S, TOF39C, TOD39C circuits.